"A Note on a Form of Magnetic Detector for Hertzian Waves, adapted for Quantitative Work." By Dr. J. A. Fleming, F.R.S., Professor of Electrical Engineering in University College, London. Received February 11,—Read March 5, 1903.

The known power of electrical oscillations to demagnetise iron or steel was first applied in the construction of a detector of Hertzian waves, as far as the author is aware, by Mr. E. Rutherford.* The power possessed by electrical oscillations to annul the magnetic hysteresis of iron was discovered by Mr. G. Marconi and applied by him in the construction of his ingenious and extraordinarily sensitive Hertzian wave detector, for use in connection with wireless telegraphy.†

The following note describes a form of magnetic Hertzian wave detector, which has been constructed by the writer for the purpose of quantitative experiments in connection with Hertzian waves.

Every one who has experimented with a Hertzian oscillator, or electric wave radiator in any form, involving a spark gap, is well aware of the immense difference in the radiative power produced by slight alterations in the nature of the spark or the spark balls, and has felt the want of some instrument which shall indicate and measure exactly the intensity of the radiation. As a receiving instrument, the coherer or sensitive imperfect contact is of very little use quantitatively, because its indications are influenced by very slight accidental changes at the contact or contacts. Thus, the sensitiveness of the metallic filings coherer depends upon the manner in which it was left after its last use, and by the mode in which it is tapped or shaken, and the change in the conductivity which it experiences on the impact of an electric wave, is variable and uncertain. Hence, although sensitive as a mere wave detector, the coherer is of little or no use in quantitative work. On the other hand, the magnetic detector is not only superior to the coherer in sensitiveness when properly constructed, but is capable of being used as a measuring instrument. In the form in which it was constructed by Mr. Rutherford, an extremely fine bundle of iron or steel wires was magnetised by means of a magnet, or by being placed in the interior of a solenoid, and then demagnetised by an electrical oscillation passing through another coil

* See Mr. E. Rutherford, "On a Magnetic Detector of Electric Waves and some of its applications," 'Roy. Soc. Proc.,' 1896, vol. 60, p. 184; see also 'Phil. Trans.,' A, 1897, vol. 189, p. 1.

† Mr. G. Marconi, "Note on a Magnetic Detector for Electric Waves which can be employed as a Receiver for Space Telegraphy," 'Roy. Soc. Proc.,' 1902, vol. 70, p. 341.

surrounding it. The amount of demagnetisation was detected by means of a magnetometer. In this form, it has been much used in experimental work, but it was not a telegraphic receiver.*

In the sensitive telegraph receiver invented by Mr. Marconi the change in magnetisation of the iron, due to the temporary abolition of hysteresis, is detected by the production of a sound in a telephone connected to a secondary coil surrounding the iron.

After trying various forms, the writer has found that a convenient magnetic detector for Hertzian waves can be constructed in the following manner :—

On a pasteboard tube, about $\frac{3}{4}$ of an inch in diameter and 5 or 6 inches long, are placed six bobbins of hard fibre, each of which contains about 6000 turns of No. 40 silk covered copper wire. These bobbins are joined in series, and form a well-insulated secondary coil, having a resistance of about 6000 ohms. In the interior of this tube are placed seven or eight small bundles of iron wire, each about 6 inches in length, each bundle being composed of eight wires, No. 26 S.W.G. in size, previously well paraffined or painted with shellac varnish. Each little bundle of iron is wound over uniformly with a magnetising coil formed of No. 36 silk-covered copper wire in one layer, and over this, but separated from it by one or two layers of gutta-percha tissue, is wound a single layer of No. 26 wire, forming a demagnetising coil. This last coil is in turn covered over with one or two layers of gutta-percha tissue.

The magnetising or inner coils are connected in series with one another, so that when a current passes through the whole of them, it magnetises the whole of the wires in such a manner that contiguous ends have the same polarity. The outer or demagnetising coils are joined in parallel. Associated with this induction coil is a rotating commutator, consisting of a number of hard fibre discs secured on a steel shaft, which is rotated by an electric motor about 500 times a minute. There are four of these fibre discs, and each disc has let in its periphery a strip of brass, occupying a certain angle of the circumference. These wheels may be distinguished as Nos. 1, 2, 3, and 4. The brass sector of No. 1 occupies 95° of its circumference; the brass sectors of Nos. 2 and 3 occupy 135° of their circumference; and that of No. 4 disc 140° of its circumference. Four little springy brass brushes make contact with the circumference of these wheels, and therefore serve to interrupt or make electric circuits as the disc revolves. The function of the disc No. 1 is to make and break the

* Note added March 7th. A general term seems to be required to include all forms of wave-detecting devices. The author suggests the word *kumascope* (from $\kappa\hat{\upsilon}\mu\alpha$, a wave) for this purpose. Uncouth phrases, such as *anticoherer* or *self-decohering-coherer*, which have crept into use in connection with Hertzian wave telegraphy, would be rendered unnecessary.

circuit of the magnetising coils placed round the iron bundles, and thus by applying a magnetising current to magnetise them during a portion of one period of rotation of the disc, and leave them magnetised in virtue of magnetic retentivity during the remaining portion. The function of discs 2 and 3 is to short-circuit the terminals of the secondary coil of the bobbin during the time that the magnetising current is being applied by disc No. 1. A sensitive movable coil galvanometer is employed in connection with the secondary coil, one terminal of the galvanometer being permanently connected to one terminal of the secondary coil, and the other terminal connected through the intermittent contact made by the disc No. 4. This disc No. 4 is so set that during the time that the secondary coil is short-circuited, and whilst the battery current is being applied to magnetise the iron wire bundles, the galvanometer circuit is interrupted by the contact on disc No. 4.

The operations which go on during one complete revolution of the discs are as follows:—First the magnetising current of a battery of secondary cells is applied to magnetise the iron bundles, and during the time this magnetising current is being applied, the terminals of the fine wire secondary coil are short-circuited and the galvanometer is disconnected. Shortly after the magnetising current is interrupted the secondary bobbin is unshort-circuited, and an instant afterwards the galvanometer circuit is completed and remains completed during the remainder of one revolution. Hence, during a large part of one revolution, the iron wire bundles are left magnetised, but the magnetising current is stopped and the galvanometer is connected to the secondary coil. If during this period an electrical oscillation is passed through the demagnetising coils, an electromotive force is induced in the secondary bobbin by the demagnetisation of the iron and causes a deflection of the galvanometer coil. Since the interruptor discs are rotating very rapidly, if the electrical oscillation continues, these intermittent electromotive impulses produce the effect of a continuous current in the galvanometer circuit, resulting in a steady deflection, which is proportional to the demagnetising force being applied to the iron, other things remaining equal. If the oscillation lasts only a very short time, the galvanometer will make a small deflection; but if the oscillation lasts for a longer time, then the galvanometer deflection is larger, and tends to become steady.

By means of such an arrangement it is possible to verify the law according to which variation falls off with distance. The instrument can be employed also as a telegraphic receiving instrument, but its chief use will be for comparing together the wave-making power of different radiators. For this purpose the oscillation coils must be connected to two long connecting wires, or one end may be connected to the earth and the other to a vertical aerial. This detector serves, for

instance, to show in a very marked manner the great effect of slight differences in the surface of the spark balls. If a steady series of sparks from an induction coil is passed between the spark balls of a Hertz linear radiator, it will produce a steady deflection on a galvanometer connected with the above-described receiver placed at a distance. If the balls are then polished, the galvanometer deflection immediately increases considerably. If, on the other hand, the balls are slightly smeared with oil, the galvanometer deflection decreases. If the radiator is approached to the receiver, or withdrawn from it, corresponding variations in the galvanometer deflection take place.

Such an instrument will probably be found of great use in connection with the design of radiators and transmitters for Hertzian wave wireless telegraphy. Up to the present it has been generally difficult to ascertain whether an improvement in the signalling is due to an accidental increase in sensitiveness in the coherer, or to any alteration or change made in the transmitter.

Similarly, the instrument promises to be of considerable use in the investigation of the transparency or opacity of various substances to Hertzian waves, not merely qualitatively, but in the determination of a coefficient of absorption. Preliminary experiments of this description made with the above-described instrument seem to promise for it a field of practical utility, both in the laboratory and in connection with Hertzian wave telegraphy.

In the numerous experiments which finally resulted in the construction of the above-described form of wave detector, it was found to be essential to have the iron core in the form of a number of small bundles of iron wire, each wound over with its own magnetising and demagnetising coil. No good results could be obtained when the iron core was in the form of a large bundle, say half an inch in diameter, and enveloped by a single magnetising and demagnetising coil.

Another condition of success is the short-circuiting of the fine wire secondary coil during the time of magnetisation of the core. The core can be indefinitely increased in size, provided the augmentation of mass is obtained by multiplying small individual cores, each consisting of not more than eight or ten fine iron wires, and each wound over with a separate magnetising and demagnetising coil. The electromotive force in the secondary coil can in this manner be increased as much as is desired, and a very sensitive wave detector produced. The commutator can be driven either by an electric motor or by any other source of power.

In conclusion, I have pleasure in mentioning the intelligent assistance rendered to me by Mr. A. Blok in the experiments conducted in connection with this appliance.